

## Comparable study for wax content and pour point in different types of crude oils

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### Abstract

#### Background:

Many types of crude oil are produced around the world. The market value of an individual crude stream reflects its quality characteristics. The quality of Sudan's oil varies substantially among fields, with a significant portion of production of relatively low quality. This comparative study considered significant because all of the major oil fields were included and most of the crude oil types were analyzed, the present study was designed with an attempt to optimize oil productivity and to study

the chemical composition of different types of crude oil in Sudan, the relationship between wax content and physical properties of crude oil and to study the pour point of crude oil.

#### Methodology:

Twenty samples collected from four different fields in the South Sudan have been investigated. By means of HPLC the samples have been separated into four chemical group classes, namely saturates, aromatics, resins, and asphaltenes, the so-called SARA fractions. Using multivariate analysis techniques such as solvent extraction to measure wax content after precipitation by controlling the temperature, also pour point were measured according to ASTM.

#### Results and Conclusion:

The results show that out of the twenty samples studied, nineteen were confirmed waxy samples (Table 1) while one was non-waxy from the pour point and wax content measurements. The

SARA analysis carried out on all of the samples on the other hand, showed the samples had a high percentage of saturates ranging from 40 wt% to 66 wt%. Sample 6 which was non-waxy crude oils even had saturates of 40%. Thus, SARA analysis data on its own might not be a tool to distinguish waxy crude oils from non-waxy crude oils. Pour point correlates fairly well to resins, aromatic and saturates,

Many experiments remain to be carried out, both to fill in data gaps, and to confirm (or deny) untested hypotheses, such as carbon number distribution using the Gas chromatography.

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## 1. Introduction and literature review

Many types of crude oil are produced around the world. The market value of an individual crude stream reflects its quality characteristics. Crude oils that are light (higher degrees of API gravity, or lower density) and sweet (low sulfur content) are usually priced higher than heavy (U.S. Energy Information Administration. 2013) Most of the studies and reviews show that the amount of oil that can be extracted with primary drive mechanisms is about 20 – 30% and by secondary recovery can reach up to 40% but using modern enhanced oil recovery (EOR) techniques, recovery can reach up to 60 – 65%. These techniques of enhanced oil recovery (EOR) are essentially designed to recover oil commonly described as residual oil. The oil that cannot be extracted by primary recovery as well as secondary recovery techniques, this amount of recovery depends on the amount of oil produced from the primary recovery (Tariq Ahmed, 2001). According to the Department of Energy U.S.A, the amount of oil produced worldwide is only one third of the total oil available. So by using the EOR techniques we will be able to produce more oil as the demand increase while we have a shortage in the supply. (Saleem Qadir Tunio, et al. 2011).

## **1.1. Oil fields:**

### **1.1.1. Adar and Gummry oil field**

The Adar oilfield, also known as the Adar Yale, Adar Yeil or Adaril field, is an oilfield situated in the Melut Basin in South Sudan estimated to contain about 276 million of oil.

### **1.1.2. Melut oil field**

The Melut Basin in South Sudan is shaping up to be one of the major sources of crude oil in Africa. The basin is located about 700 miles south of Khartoum east of the river Nile and despite the political difficulties in the area, the development has continued with a number of companies actively participating in the construction of marine export terminal facilities for the project, of 1380 km of export pipeline constructed in 4 segments (A1, A2, B1 and B2) or in the construction of the six pumping stations for the pipeline. At the moment, one of the latest projects include the design and construction of new field processing facilities for a supplementary oil field at Moleeta, which is expected to increase the Sudanese oil production by over 50,000 bpd. Most of the proven reserves of crude oil and natural gas of Sudan and South Sudan are located in the Muglad and Melut basins, which extend into both countries. According to the BP (2013) Statistical Review of World Energy, South Sudan has approximately 3.5 billion barrels of proven reserves, while those of Sudan are put at 1.5 billion barrels.

### **1.1.3. Palogue oil field**

The Palogue oil field is an oil field located in Melut Basin. It was discovered in 2003 and developed by China National Petroleum Corporation. It began production in 2003 and produces oil. The total proven reserves of the Palogue oil field are around 2.9 billion barrels and production is centered around 22,000 barrels per day.

## 1.2. Chemical and Physical Properties of Crude Oils

Crude oils are mixtures of hydrocarbon compounds ranging from smaller, volatile compounds to very large, nonvolatile compounds. The hydrocarbon structures found in oil include saturates, aromatics, and polar compounds that include resins and asphaltenes. The resins and asphaltenes are largely recalcitrant in the environment. They evaporate, dissolve, and degrade poorly and thus may accumulate as residues after a spill.

The distinct physical and chemical properties of diluted bitumen arise from two components: the bitumen provides the high-molecular-weight components that contribute most to density, viscosity, and adhesion; and the diluent contributes the low-molecular-weight compounds that confer volatility and flammability, and that determine the rate at which evaporation increases the density of the residual oil.

Because diluted bitumen has higher concentrations of resins and asphaltenes than most crude oils, spills of diluted bitumen products will produce relatively larger volumes of persistent residues. Such residues may be produced relatively rapidly when gas condensate has been used as the diluent, and these weathered residues display striking differences in behavior compared to other oils: exceptionally high levels of adhesion, density, and viscosity. (Hollebone, B., 2015)

## 1.3. Wax in crude oil

Waxes present in crude oil are considered to be responsible for its poor flow properties. Bombay high crude is very waxy and has a pour point of + 30 °C. The influence of nature and concentration of waxes on some of the flow properties, namely pour point, plastic viscosity and yield stress, of dewaxed Bombay high crude have been determined. The hard wax components present in the crude do not appear to significantly influence the low temperature rheology of the crude oil, but do contribute to sludge formation. (K.M.Agarwal;et al,1989)

Many crudes contain dissolved waxes that can precipitate and deposit under the appropriate environmental conditions. These can build up in production equipment and pipelines, potentially restricting flow (reducing volume produced) and creating other problems. Precipitated wax has pronounced effect on kinematic viscosity and pour point of crude oils..(A. MajhiY. K., 2015)

Paraffin wax produced from crude oil consists primarily of long chain, saturated hydrocarbons (linear alkanes/ *n*-paraffins) with carbon chain lengths of C18 to C75+, having individual melting points from 40 to 70°C. This wax material is referred to as “macrocrystalline wax.” Naphthenic hydrocarbons (C18 to C36) also deposit wax, which is referred to as “microcrystalline wax.” Macrocrystalline waxes lead to paraffin problems in production and transport operations; microcrystalline waxes contribute the most to tank-bottom sludges. (Garcia, et al, 1998) The *n*-heptane structure is an example of a “normal” paraffin; 2-methyloctane is an “iso” paraffin and *n*-butylcyclopentane is a naphthene. These specific *n*-paraffins and naphthenes are too small to crystallize as wax deposits (i.e., outside the carbon-number range specified above). The drawings illustrate the type of structures involved.

Waxes isolated from crudes can contain various amounts of all classes: *n*-paraffins, naphthenes, and iso-paraffins. For example, waxes derived from several Venezuelan crudes (Garcia, et al, 1998) showed *n* -paraffin/(cyclo + iso paraffin) ratios ranging from 1.28 to 0.23. The iso-paraffins of the 2-methyloctane type (**Fig. 3**) are more likely to be included in a wax deposit than the more highly branched alkanes.

A “clean waxy crude” is defined as a crude oil that consists of only hydrocarbons and wax as the heavy organic constituents. “Regular waxy crudes” contain other heavy organics in addition to the waxes (e.g., asphaltenes and resins). These heavy organics have interactions with the crude, which can either prevent wax-crystal formation or enhance it.

### 1.3.1. Solvent dewaxing:

Wax deposition is one of the chronic problems in the petroleum industry. The various crude oils present in the world contain wax contents of up to 32.5%. Paraffin waxes consist of straight chain saturated hydrocarbons with carbon atoms ranging from C18 to C36. Paraffin wax consists mostly with normal paraffin content (80–90%), while, the rest consists of branched paraffins (iso-paraffins) and cycloparaffins. The sources of higher molecular weight waxes in oils have not yet been proven and are under exploration. Waxes may precipitate as the temperature decreases and a solid phase may arise due to their low solubility. For instance, paraffinic waxes can precipitate out when temperature decreases during oil production, transportation through pipelines, and oil storage. The process of solvent dewaxing is used to

remove wax from either distillate or residual feedstocks at any stage in the refining process. The solvents used, methyl-ethyl ketone and toluene, can then be separated from dewaxed oil filtrate stream by membrane process and recycled back to be used again in solvent dewaxing process.(Mohamed rehan;et al, 2016)

### 1.3.2. Wax deposition

Wax deposition is one of the serious problem in oil industry. It has got a crucial attention to overcome this issue in more hostile environment in new oil fields exploration especially in deep water. Waxes, that are known as mostly heavy saturated paraffins, tend to precipitate when the temperature and pressure of oil fields drop during the production and transportation. Wax Appearance Temperature (WAT) determines the deposition of the wax on the reservoir or pipelines when the temperature of the reservoir or production line falls below the WAT. WAT is regularly used to measure the tendency of a crude oil to produce wax in relation with pressure and temperature reduction. In simple words, WAT is the temperature at which the first wax crystal appears. Wax deposition will be complex and costly. It will cause a lot of difficulties in blocking of transport equipments and pipelines. If not treated, well can eventually decrease or in worst condition block the flow in production line or even in well (Sanjay *et al.*, 1995; Merino-Garcia and Corraera, 2008; Al-Yaari, 2011; Taraneh *et al.*, 2008; Alghanduri *et al.*, 2010; Zhu *et al.*, 2008; Elsharkawy *et al.*, 2000; Aiyejina *et al.*, 2011).

As the temperature of the crude drops below a critical level and/or as the low-molecular-weight hydrocarbons vaporize, the dissolved waxes begin to form insoluble crystals. The deposition process involves two distinct stages: nucleation and growth. Nucleation is the forming of paraffin clusters of a critical size (“nuclei”) that are stable in the hydrocarbon fluid. This insoluble wax itself tends to disperse in the crude.

Wax deposition onto the production system (“growth”) generally requires a “nucleating agent,” such as asphaltenes and inorganic solids. The wax deposits vary in consistency from a soft mush to a hard, brittle material. Paraffin deposits will be harder, if longer-chain n-paraffins are present. Paraffin deposits can also contain: (Allen, et a,1982)

- Asphaltenes

- Resins
- Gums
- Fine sand
- Silt
- Clays
- Salt
- Water

High-molecular-weight waxes tend to deposit in the higher-temperature sections of a well, while lower-molecular-weight fractions tend to deposit in lower-temperature regions. Prior to solidification, the solid wax crystals in the liquid oil change the flow properties from a Newtonian low viscosity fluid to a very-complex-flow behavior gel with a yield stress. In order to overcome wax deposition problem, the better understanding of the physical characterization of crude oil is necessary. Viscosity, density and pour point are properties that ascertain handling characteristics of crude oils. In this study, crude oils from Malaysian oil fields are studied to determine their wax formation tendency for flow assurance purposes. For this study, density, viscosity and pour point of all crude oils is measured by digital den-sity meter (DMA 4500 M), advanced AR-G2 rheometer and D-97 ASTM methods, respectively. Result showed that there is linear trend between density and temperature. In general, wax precipitation and deposition has direct relationship with wax content of crude oil. Moreover, the shear rate has considerable effect on viscosity reduction. Temperature reduction causes viscosity to increase. However, it is against shear rate that tends to lower it. (Andhy Arya Ekaputra; et al, 2014)

### 1.3.3. Coping with waxes

The primary chemical parameter to establish is the critical temperature at which these wax nuclei form—the wax appearance temperature (WAT). The WAT (or “cloud point”) is highly specific to each crude. The WAT value is a function of. (Hammami, 1997)

- Oil composition
- Cooling rate during measurement
- Pressure

- Paraffin concentration
- Molecular mass of paraffin molecules
- Occurrence of nucleating materials such as asphaltenes, formation fines, and corrosion products
- Water/oil ratio
- Shear environment

A variety of experimental methods have been used to obtain this number. Among these are:

- Differential scanning calorimetry (DSC) - measures the heat released by wax crystallization
- Cross polarization microscopy (CPM) - exploits the fact that insoluble wax crystals rotate polarized light, but liquid hydrocarbons do not
- Filter plugging (FP) - measures the increase in differential pressure across a filter, which can be attributed to wax-crystal formation
- Fourier transform infrared energy scattering (FTIR) - detects the cloud point by measuring the increase in energy scattering associated with wax solidification

Each of these techniques has its advantages and disadvantages. A comparison/review of these methods is found in Monger-McClure, et al. (Monger-McClure, 1997) In testing, cloud points, measured by each of the four methods, agreed with the average value of all methods within 3 to 5°F.

Of more importance, is how well laboratory-measured cloud points anticipate WATs found in the field. Measured cloud-point data should only match field results for wells producing at low shear (high shear rates tend to delay the deposition of waxes). Another inherent problem is that the cloud-point measurement sees the precipitation of the most insoluble paraffin, not the mass of lower-molecular-weight paraffins that might contribute the major amount of wax deposit. Nevertheless, CPM measurements have been found to correlate well with the temperature at field deposition, more so than optical techniques that required a greater mass of wax to register a signal.[3] A major problem in correlating these measurements and simulations with field experience is the acquisition of good field data. (Monger-McClure, 1997) Illustrative of the state



of the art in interpreting these measurements is that closer agreement is found between stock-tank oil measurements and field experience, even though it is live oil that is being produced.

An alternative to the measurement of cloud point is its prediction from compositional data by thermodynamic models. These models can predict cloud point as the temperature at which the first infinitesimal amount of wax appears, as well as predicting that mass of wax precipitating out of solution that, from experience, corresponds to field deposition. (Calang, et al, 1997) Models that use detailed n-paraffin composition input data, as obtained from high-pressure gas chromatography, generally outperform models based on less specific information like compositions to C7+ [the numbers are more generally available in the routine pressure/volume/temperature (PVT) reports].

#### 1.3.4. Paraffin deposition models

Given the cloud point, what is the propensity for wax precipitation during the production and, in particular, the pipelining and processing of the crude? This is the regime of “paraffin deposition models.” These are engineering simulators used to predict wax buildup in flowing systems, (Brill, J. 1997) taking into account such parameters as:

- Heat transfer
- Phase behavior of the crude
- Flow regime
- Wax deposition kinetics
- Shear rate
- Diffusivity
- Wall conditions (roughness, coatings, scale)
- Produced-water/oil ratio

Paraffinization is one of the main problems in oil production and causes considerable losses to the oil industry. The wax precipitation phenomenon associated with paraffin deposition can result in unscheduled production shutdowns and promote operational risk conditions. Moreover, it can cause production losses and irreparable damage to equipment (Pauly *et al.*, 2004).

In the Bahian Recôncavo region, the produced crude oil exhibits a density of approximately 30° API, almost no sulfur and high concentrations of dissolved waxes. Although these properties are great for the manufacture of lubricant oils and yield high added value, the presence of wax adds many complications to production, transportation and storage by hindering the flow in pipes (Thomas, 2004; Novaes, 2009).

Paraffins are both linear (n-paraffins) and branched (iso-paraffins) chain alkanes, and they have low reactivity with most compounds. Their chains can have a high carbon number, which implies a higher wax appearance temperature. The low-molecular-weight paraffins are the main components of natural gas, and the medium- and high-molecular-weight ones are found in crude oil (Farayola *et al.*, 2010; Gao, 2008; Jamaluddin *et al.*, 2001).

Paraffins are in equilibrium with other crude oil components, and any change in pressure, temperature and even composition can affect the equilibrium, thereby influencing the formation of precipitate. According to Santos (1994), the greater the crude oil wax content, the greater the precipitation rate and, therefore, the amount of precipitated wax. The light oil components keep the waxes soluble. The high pressure of the reservoirs maintains the light compounds solubilized in the crude oil, which favors the solubilization of waxes in the fluid (Tinsley; Prud'Homme, 2010). This condition ensures low viscosity and Newtonian behavior of the crude oil (Azevedo, 2003).

Temperature also influences the solubility of waxes in crude oil. When approximately 5% of the waxes crystallize because of oil cooling, a crystal lattice appears and traps some of the oil inside; this process is called "gelling" and hinders the fluid flow. Thus, the crude oil flow rate also interferes with wax solubility. The lower the oil flow rate, the longer it stays inside the piping, which favors heat exchange with the external environment (Vieira, 2008).

Once production starts, the oil flows through the pipelines, losing heat to the external environment, with consequent temperature decreases and reduced soluble light oil fractions. Such production conditions cause the oil viscosity to increase, which leads to production problems due to the precipitation of waxes (Venkatesan *et al.*, 2005; Gao, 2008).

According to Vieira (2008), the first paraffin crystals start to form at a specific temperature, which is called the wax appearance temperature (WAT) and varies depending on the origin of the crude oil. Crystallization occurs in three steps:

- Nucleation - formation of small particles of crystallized material from which the first paraffin crystals will grow.
- Growth - mass transport of the solution towards the nuclei formed during the nucleation stage.
- Agglomeration - when the growing crystals are joined together, thereby yielding larger crystals.

With the nuclei already formed, there is incorporation of new paraffin molecules at the growth sites, and additional molecules of other species are grouped at these sites and become part of the structure. The nuclei form an ordered lamellar-structure arrangement.

After crystallization starts in a medium that contains water as an emulsion, the crystal lattice formation phenomenon occurs in a different manner. When the emulsion is of the water-in-oil type, the oil is waxy and the fluid temperature is below the WAT, the precipitated waxes are deposited onto the surface of the water drops, thereby contributing to the growth of the formed precipitate (Oliveira et al., 2010). When a large crystal lattice is in the vicinity of the water drops, a structure is formed; this structure percolates the drops into the lattice and captures them. According to Visitin (2008), this structure also provides mechanical resistance to the flow, thereby resulting in an increase in the viscosity and pour point of the oil.

### **1.3.5. Prevention/inhibition**

As with other solids-depositing problems, prevention can be more cost effective than removal. One key to wax-deposition prevention is heat. Electric heaters can be employed to raise the crude oil temperature as it enters the wellbore. The limitations are the maintenance costs of the heating system and the availability of electrical power. As with hydrates, maintaining a sufficiently high production level may also keep the upper-wellbore temperature above the WAT. In addition, high flow rates tend to minimize wax adherence to metal surfaces because of the shearing action

of the flowing fluid. Insulated pipelines are also an alternative to minimize, if not eliminate, the problem, but the cost can be prohibitive for long pipelines.

Wax deposition can be prevented, delayed, or minimized by the use of dispersants or crystal modifiers. As with asphaltenes, paraffin-wax characteristics vary from well to well. Chemicals that are effective in one system are not always successful in others, even for wells within the same reservoir. “For this reason it is of fundamental importance to establish a good correlation between oil composition and paraffin inhibitors efficiency, leading to an adequate product selection for each particular case, avoiding extremely expensive and inefficient ‘trial-and-error’ procedures.” (Garcia, et al,1998)

### 1.3.6. Crystal modifiers

Paraffin-crystal modifiers are chemicals that interact with the growing crude-oil waxes by cocrystallizing with the native paraffin waxes in the crude oil that is being treated. These interactions result in the deformation of the crystal morphology of the crude-oil wax. Once deformed, these crystals cannot undergo the normal series of aggregation steps. Types of paraffin-crystal modifiers include:

- Maleic acid esters
- Polymeric acrylate and methacrylate esters
- Ethylene vinyl acetate polymers and copolymers

### 1.3.7. Dispersants

Dispersants act to keep the wax nuclei from agglomerating. Dispersants are generally surfactants and may also keep the pipe surface water wet, minimizing the tendency of the wax to adhere. Some water production is required, of course. High levels of water alone may maintain the system in a water-wet state. As with scale prevention, a smooth surface tends to decrease wax adherence. However, the operational problem is to maintain such a surface for an extended period of time. Various forms of erosion are highly detrimental.

Obviously, these inhibitors must be delivered into the crude oil at temperatures above the WAT. This need not cause a problem for surface equipment, but it could cause a problem for wellbore treatment, if the bottom hole temperatures are low.

### 1.3.8. Removal of deposits

Removal of wax deposits within a wellbore is accomplished by:

- Cutting
- Drilling
- Chemical dissolution
- Melting—the use of hot oil, hot water, or steam

Of these, the use of hot oil has been the most popular, normally pumped down the casing and up the tubular. It is intended that the high temperature of the liquid phase heat and melt the wax, which then dissolves in the oil phase. Using the bottom-up delivery approach, hot oil first reaches those waxes most difficult to melt. The higher in the tubular the hot oil proceeds, the lower its temperature becomes, thereby reducing its wax-carrying capacity. Hot oiling can cause permeability damage, if the fluid containing the melted wax enters the formation. ( Allen, et al, 1982)

Hot water, hot-water/surfactant combinations, and steam are alternatives to hot oiling. Plain hot-water treatments do not provide the solvency required to remove the wax, hence the use of surfactants to disperse the wax. The advantage of water is its greater heat capacity.

Chemical generation of heat has also been proposed as a method of melting wax deposits. One field-tested scheme uses the thermo-chemical process of reacting two specific nitrogen salt solutions, acidic ammonium chloride and sodium nitrite ( Khalil, et al, 1997) an organic solvent is included to keep the wax in solution after the system has cooled.

Various aromatic solvents can be used to dissolve the wax. These are generally not heated, relying solely on the solvency properties of the fluid. As with asphaltene dissolution, o-xylene has been one of the more effective solvents for waxes. Kerosene and diesel tend to be poor solvents. However, as with asphaltene dissolution, one solvent does not necessarily work

equally well on all wax deposits; an example of solvent screening procedures is given in Ferworn, et al.(1997)

Pigging is the primary mechanical method of removing wax buildup from the internal walls of pipelines. The pig cuts the wax from the pipe walls; a bypass can be set with a variable-flow pass, allowing the pig to prevent wax buildup in front. Pig sizing can vary, and multiple pig runs with pigs of increasing size can be used. For subsea pigging, a looped flow-line is required or a subsea pig launcher for a single flow-line. The major uncertainty in this operation is the wax hardness as it is formed in the pipeline.

Coiled tubing with the appropriate cutters at the end also can be used for wax removal—the drawback for pipeline cleaning being the limited reach of the coiled tubing. For wellbore cleaning this is obviously less of a problem.

#### **1.4. Objects**

To study the chemical composition of different types of crude oil in Sudan.

To study the relationship between chemical composition and physical properties of crude oil.

## **2. Methodology:**

### **2.1. Study Subjects**

A crude oil samples were taken from four different fields from Upper Nile state:

Adar oil field

Palogue oil field

Gummry oil field

Melut oil field

#### **Inclusion criteria**

- Samples from all petroleum field in the area of Upper Nile state Were included in the study.

**Exclusion criteria**

- Fields far away in the country of South Sudan were excluded from the study; For example the Adar field (Qassabi)

**2.2. Weaknesses and strength**

The weaknesses were that only four fields were included in the study and not all of the crude oil types were included. When South Sudan gained its independence in 2011, it had control over most of the areas that were producing oil.

Study strength; the four major fields of crude oil were included in the study.

**2.3. Experimental, materials, apparatus and methods**

Four different petroleum fields were included in the study. This study was carried out using different types of crude oil, analysis for these samples were conducted to determine the viscosity, density, API, pour point, base sediment, water cut, wax content, asphaltene content and SARA test. HPLC and GC-MS were used to study the light constituents of the crude oil. According to ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS ) the pour point, water cut & base sediment, density & API, viscosity, wax content, asphaltene content of the samples were measured.

**2.3.1. Standard Test Method for Determination of Wax ASTM**

UOP 46-85 The sample is dissolved in methyl ethyl ketone, the solution cooled to  $-32^{\circ}\text{C}$  to precipitate the wax, and filtered. The oil content of the filtrate was determined by evaporating the methyl ethyl ketone and weighing the residue.

**2.3.2. Standard Test Method for Determination of Pour point ASTM D 97**

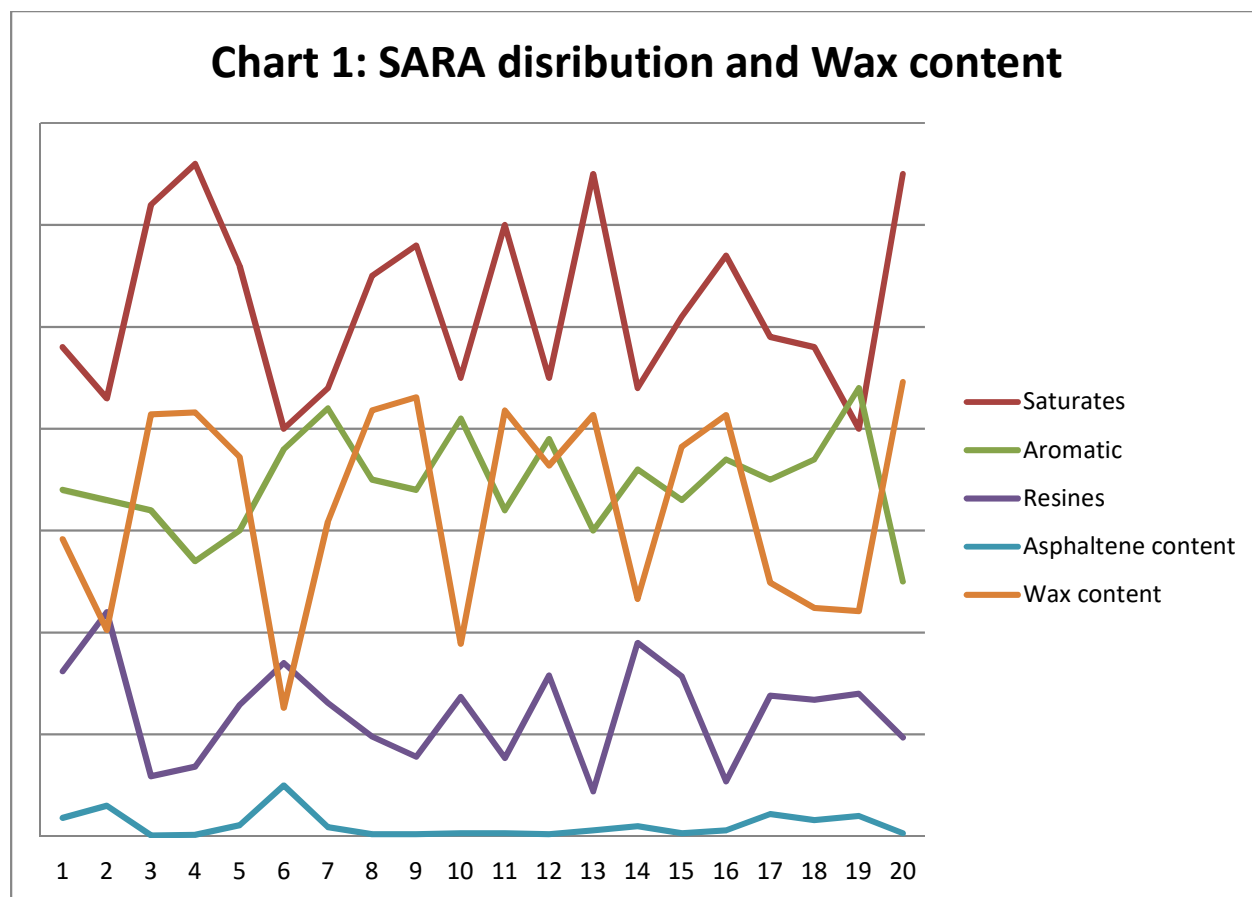
After preliminary heating, the sample was cooled at a specified rate and examined at intervals of  $3^{\circ}\text{C}$  for flow characteristics. The lowest temperature at which movement of the specimen was observed was recorded as the pour point.

### 3. Results and discussion

Table 1: SARA distribution and Wax content

Sample	<i>Saturates</i>	Aromatic	Resins	<i>Asphaltene content</i>	<i>Wax content</i>
1	48	34	16.2	1.8	29.17
2	43	33	22	3	20.24
3	62	32	5.9	0.1	41.4
4	66	27	6.84	0.16	41.6
5	56	30	12.9	1.1	37.24
6	40	38	17	5	12.6
7	44	42	13.1	0.9	30.9
8	55	35	9.8	0.2	41.8
9	58	34	7.8	0.2	43.07
10	45	41	13.7	0.3	18.9
11	60	32	7.7	0.3	41.78
12	45	39	15.8	0.2	36.4
13	65	30	4.4	0.6	41.34
14	44	36	19	1	23.3
15	51	33	15.7	0.3	38.23
16	57	37	5.4	0.6	41.34
17	49	35	13.8	2.2	24.9
18	48	37	13.4	1.6	22.4
19	40	44	14	2	22.1
20	65	25	9.7	0.3	44.59



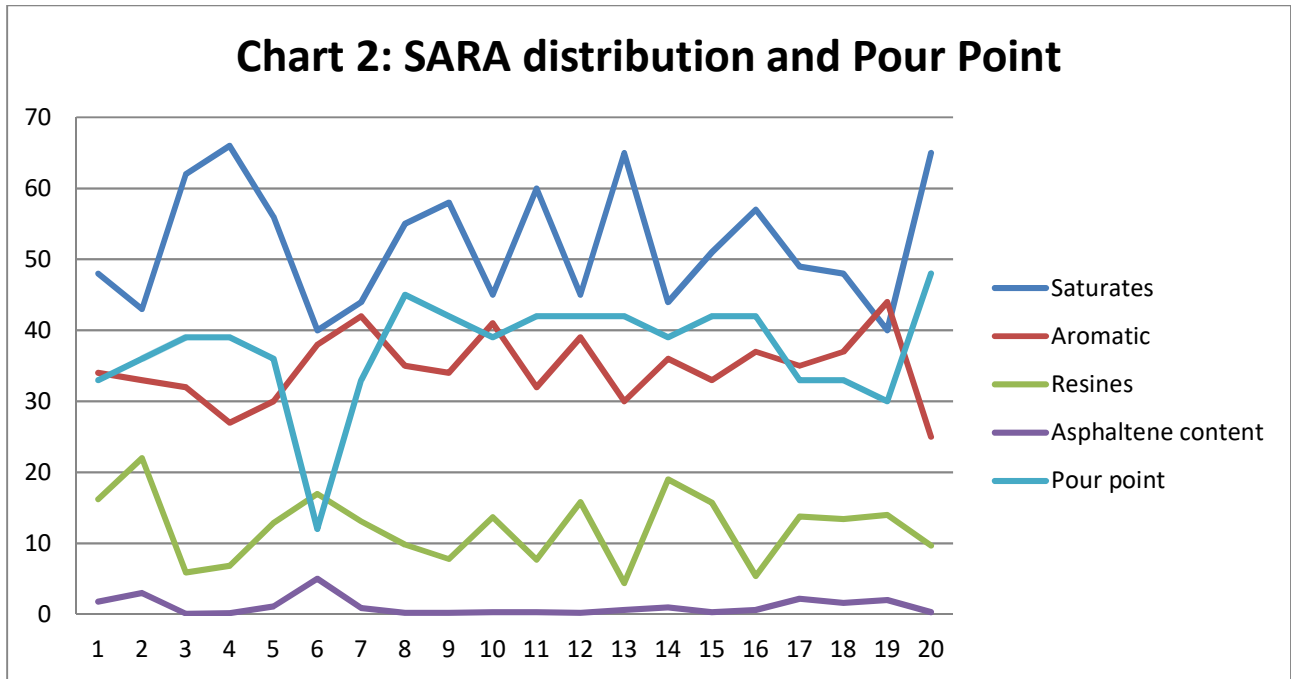


Separation of crude oil into hydrocarbon fractions such as saturate, aromatic, resin and asphaltene (SARA) fractions is needed in order to obtain the concentration of each group. This chemical analysis of crude oil is necessary for upstream, midstream and downstream operations; as it yields information such as crude oil stability (asphaltenic stability), fouling propensity and the blending compatibility of the crude oil. Since SARA analysis can give information on asphaltenic stability, there is need to investigate the use of this analysis for wax precipitation tendency or wax instability. In this work twenty samples collected from four different fields in the South Sudan were studied. The modified ASTM D2549–02 was employed to separate the crude oil samples into their various chemical species. pour point and wax content were measured on the samples as well to determine whether they were waxy crude oils or non-waxy crude oils. Out of the twenty samples studied, nineteen were confirmed waxy samples (Table 1) while one was non-waxy from the pour point and wax content measurements. The SARA analysis carried out on all of the samples on the other hand, showed the samples had a high percentage of saturates ranging from 40 wt% to 66 wt%. Sample 6 which was non-waxy crude

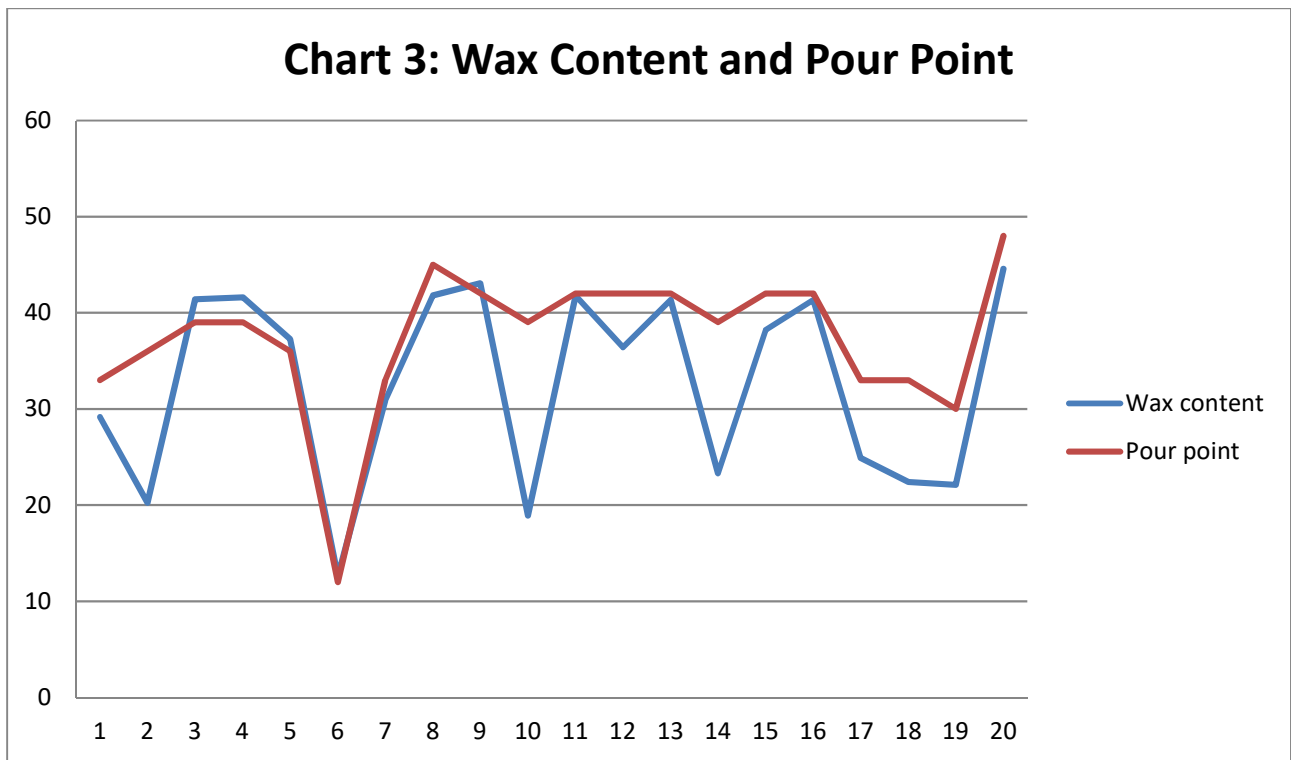
oils even had saturates of 40%. Thus, SARA analysis data on its own might not be a tool to distinguish waxy crude oils from non-waxy crude oils. This goes in consistency with the study of (Bella Mmata et.al. 2017) were the researcher studied thirteen samples collected from three different fields in the Niger Delta region were studied.

**Table 2: SARA distribution and Pour Point**

<b>Sample</b>	<b><i>Saturates</i></b>	<b>Aromatic</b>	<b>Resins</b>	<b><i>Asphaltene content</i></b>	<b>Pour point</b>
1	48	34	16.2	1.8	33
2	43	33	22	3	36
3	62	32	5.9	0.1	39
4	66	27	6.84	0.16	39
5	56	30	12.9	1.1	36
6	40	38	17	5	12
7	44	42	13.1	0.9	33
8	55	35	9.8	0.2	45
9	58	34	7.8	0.2	42
10	45	41	13.7	0.3	39
11	60	32	7.7	0.3	42
12	45	39	15.8	0.2	42
13	65	30	4.4	0.6	42
14	44	36	19	1	39
15	51	33	15.7	0.3	42
16	57	37	5.4	0.6	42
17	49	35	13.8	2.2	33
18	48	37	13.4	1.6	33
19	40	44	14	2	30
20	65	25	9.7	0.3	48



As shown in chart 9 above, pour point correlates fairly well to saturates, aromatics and resins but we can find better correlation between wax content and pour point as shown in chart 10



#### 4.1. Conclusion:

In this study twenty samples collected from four different fields in the South Sudan were studied. The modified ASTM D2549–02 was employed to separate the crude oil samples into their various chemical species. Pour point and wax content were measured on the samples as well to determine whether they were waxy crude oils or non-waxy crude oils.

Based on the results of the present study it can be concluded that out of the twenty samples studied, nineteen were confirmed waxy samples (Table 1) while one was non-waxy from the pour point and wax content measurements. The SARA analysis carried out on all of the samples on the other hand, showed the samples had a high percentage of saturates ranging from 40 wt% to 66 wt%. Sample 6 which was non-waxy crude oils even had saturates of 40%. Thus, SARA analysis data on its own might not be a tool to distinguish waxy crude oils from non-waxy crude oils.

Pour point correlates fairly well to resins, aromatic and saturates,

#### 4.2. Recommendations:

Most types of crude oil were waxy oil in these fields, so the main problem will be the wax precipitation, wax inhibitors or pour point depressants should be injected to many wells.

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#### List of abbreviations

API: American Petroleum Institute.

ASTM: American Society for Testing and Material

GC: Gas Chromatography.

HPLC: High Performance Liquid Chromatography.

SARA: Saturate Aromatic Resin asphaltine.

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